Ch. 17 The Universe Observed

4-17-19

Composition of the Universe

$\sim 10^{11}$ Galaxies w/ 10^{11} Stars / Galaxy
$\Rightarrow$ if smoothed out
$\rho_{visible}(t_0) \sim 10^{-31}\, g/cm^3 \Rightarrow$ Roughly 1 proton per m^3

Radiation $t_0 \rightarrow$ Time as of today

$\rho_r(t_0) \sim 10^{-34}\, g/cm^3 \ll \rho_{visible}(t_0)$: r - radiation

Dark Matter

For a galaxy:

$$\frac{GmM(r)}{r^2} = \frac{mV^2(r)}{r} \quad \therefore V(r) = \sqrt{\frac{GM(r)}{r}} \sim r^{-1/2}$$

This is not seen! Instead $V(r) \sim$ const.
$\Rightarrow M(r) \sim r$

$\Rightarrow$ Almost every galaxy contains a halo of dark, unseen matter

$\sim$ Ten times the mass seen in visible light!

Dark Energy

- Constant vacuum energy comprising $\sim 70\%$ of the total MBS-energy of the universe

The Expanding Universe

$$\frac{V}{c} = \frac{\Delta\lambda}{\lambda} \equiv z$$

For sufficiently close galaxies ....

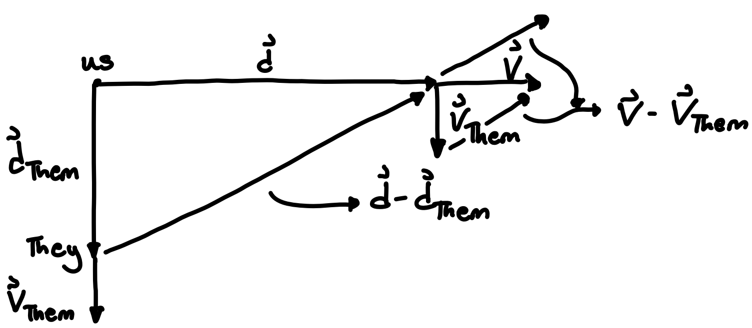
$\left[V = H_0 d \right]$ - Where expansion velocity dominates over other velocities
where $H_0 = (72 \pm 7) \frac{km}{S \cdot MPC}$: 1 pc = 3.26 c.yrs

In vector form...

$$\vec{V} = H_0 \vec{d}$$

For a particular galaxy located at $\vec{d}_{Them}$...

$$\vec{V} - \vec{V}_{Them} = H_0 (\vec{d} - \vec{d}_{Them})$$



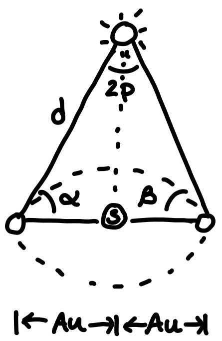
Observers in that galaxy also see expansion governed by Hubble's Law!

4-24-19

Cosmology

$v = H_0 d$

How do we determine the distance to near by stars



$2p = \pi - \alpha - \beta$

where p is the paralax for some angles p

$\sin(p) \simeq p \simeq \frac{1\,Au}{d} \quad \therefore \quad d = \frac{Au}{p}$

Hipparacos Astronomical Satellite has determined the distance above about 20,000 stars.
w/ 15,000 within 100 pc < $10^{-7}\times$ size of the visible universe

How do we find the distance to the Rest?
⇒ Standard Candle
- An object whose Luminosity can be informed from a physical property that can be independently determined....

L is Luminosity of near by star

f is Apparent Brightness (Energy flux @ Earth)

d is Distance

$\left[f = \frac{L}{4\pi d^2} \right]$ measure f, know d, get L

what if we know L?

$d = \left(\frac{L}{4\pi f} \right)^{1/2}$

Know L, measure f, get d

3 Different Standard Cases......

- The MHW Sequence
- Cepheid Variable Stars

⇒ Empirical relationship between Absolute Luminosity : Period of their Variation

For distant Cepheid Variables.....
Measure apparent brightness

: Period ⇒ Absolute Luminosity

Determine distance